SPATIAL DISTRIBUTIONS OF STOCKING INTENSITY PRODUCED BY SHEEPFLOCKS GRAZING AUSTRALIAN CHENOPOD SHRUBLANDS

by ROBERT T. LANGE*

Summary

LANGE, R. T. (1985) Spatial distributions of stocking intensity produced by sheepflocks grazing Australian chenopod shrublands. *Trans. R. Soc. S. Aust.* **109**(4), 167-174, 29 November, 1985.

The distribution of estimated sheep stocking intensity (ha sheep^{-1}) is described from within each of several paddocks (large wire-fenced subdivisions) of arid zone stations (ranches) in Australia. The estimation method is based on demonstrated proportionality between time spent and egesta deposited by sheep in the localities they visit. Egesta deposition measurements of which the intensity estimates are transformations are shown experimentally to correlate with immediate sheep effects upon the vegetation.

The magnitudes of estimated sheep stocking intensity are shown to vary greatly from place to place within the one paddock. In the studied region about one third of each paddock's area experienced intensities higher than the paddock average, grading upwards to about six times higher, while about two thirds experienced lower intensities grading down to zero. Implications for perennial vegetation in the paddocks are discussed.

KEY WORDS: Chenopod shrubland, sheep grazing, stocking pressure variation.

Introduction

Sheep pastoralism in the Australian arid zone is notable for its great wool production but also for the damage which the sheep do to the perennial vegetation. There is a general belief that there are safe stocking intensities which do not harm the vegetation and excessive intensities ("overstocking") which do. Many authors have used small-paddock experimental trials (of area one ha or so) to demonstrate the relevant relationships between stocking intensity and vegetation reactions (Cunningham & Walker 1973; Hamilton & Bath 1970; Harrington 1979; Leigh & Mulham 1966; Leigh & Wilson 1969; Leigh, Wilson & Mulham 1968, 1969; Trumble & Woodroffe 1954; Tupper 1978; Williams 1970; Wilson 1974, 1976; Wilson & Graetz 1980; Wilson, Leigh & Mulham 1969; Wilson, Mulham & Leigh 1976).

The application of their results to full scale pastoral paddocks is complicated because flocks do not spend their time evenly throughout the large areas in which they wander (Waite 1896; Osborn, Wood & Paltridge 1932; Valentine 1947; McBride, Arnold, Alexander & Lynch 1967; Barker 1979; Squires 1970, 1974; Whalley, Robinson & Taylor 1978). So although the paddock average stocking intensity may be known (PSI = enclosure area divided by flocksize), the intensity on any actual part (SIP = average stocking intensity of the part) remains unknown. Without some means of estimating SIP at given points within paddocks, there is no connection with the experimental-trial literature. The difficulties of this situation were pointed out by Rawes & Welch (1966, 1969), Ares & Leon (1972) and Anderson & Currier (1973).

An approximate solution to these difficulties follows demonstrations by Rawes & Welch (1966, 1969), Lange (1969), Ares & Leon (1972), Squires (1974), Lange & Willcocks (1978) and others, that quantitative relationships exist between flock use of pasture localities and the amounts of egesta which fall in them. From these relationships SIP can be estimated. A particular basis demonstrated by Lange (1983) is used here to examine the spatial and temporal distribution of estimated SIP in arid zone paddocks of the Whyalla region, South Australia, during the period 1969-1982.

Methods

Computations and Graphical Summaries

As in the study of Hilder (1964) the enclosure (paddock) is imagined to be divided into many equal parts from each of which egesta accumulations can be measured. Over any observational timespan the exact average stocking intensity on each part (Lange 1983) then is:

$$\frac{\text{area of the part (ha)}}{\text{enclosure flocksize} \times \text{fraction of total flocktime spent in the part } (=F)} = \text{SIP (ha sheep}^{-1})$$

The use of ha sheep^{-1} rather than its reciprocal follows Harrington (1979), Cunningham & Walker (1973), Rattray (1960), Goodall (1971) and Vesey-Fitzgerald (1974) because in the arid zone it mostly has values >1. Except in small-scale calibration experiments (Lange & Willcocks 1978; Lange 1983) there was no practicable means of obtaining F

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directly because canopies of the western myall trees (*Acacia papyrocarpa* Benth) prevented surveillance even from a tower. Egesta accumulations in contrast were easily measured and had the special advantage of reflecting total flock activity at all times in all places.

An approximate SIP was obtained for each part by substituting the fraction of enclosure total egesta deposition on the part as a surrogate for F (the fraction of total flocktime spent in the part). In this study that substitution rested on 3 experimental demonstrations in the Whyalla region, that sheeptime spent on a part was roughly proportional to egesta recovered from it (r^2 = 0.92 to 0.98, p <0.001). This proportionality was subject to the requirement that the size of the part, the length of the accumulation span and the size of the egesta sample were all relatively large (Lange 1983).

As in similar studies (Rawes & Welch 1966, 1969; Ares & Leon 1972; Squires 1974; Hilder 1964), egesta on the part was sampled, in this case from 240 m^2 of ground surface per part. Over protracted periods it was recovered, oven dried, weighed, volumed and stored every few weeks to avoid field decay losses.

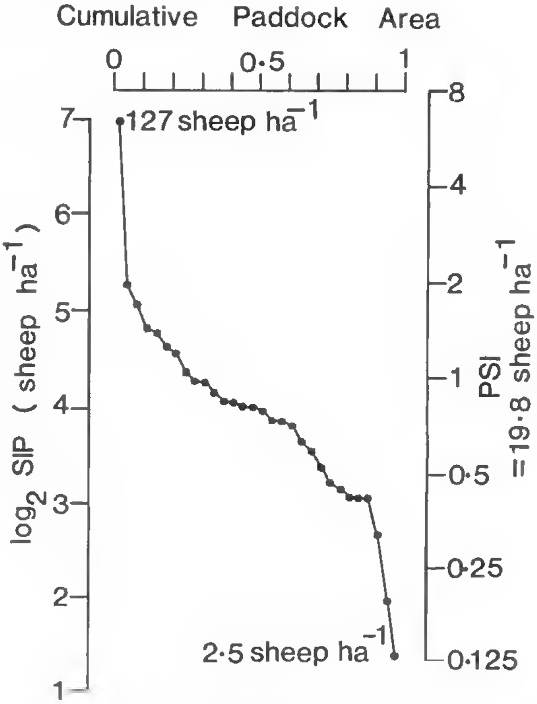

Fig. 1. The cumulative distribution of $\log_2$ SIP (stocking intensity of the part) for the 30 parts of the sheep-stocked enclosure described by Hilder (1964). The right-hand scale expresses SIP variation in terms of PSI (paddock average stocking intensity). In this case sheep ha^{-1} rather than its reciprocal is used because of the very high stocking intensity.

The first form of graphical summary was the paddock cumulative distribution of $\log_2$ SIP as shown in Fig. 1 which was prepared as an example from published data of Hilder (1964, his Fig. 1). This summary is directly comparable in preparation and applications to the cumulative probability distribution P_x of a normal distribution (Smith 1954, his p. 581) which in most cases it approximates. Log x is used to compress and normalize SIP scores which vary greatly even from very small heavily stocked enclosures (Hilder set 20 sheep in just over 1 ha). $\log_2$ is used because published data about the sensitivity of vegetation to SIP are from factorial experiments involving an SIP doubling scale (e.g. Wilson, Leigh & Mulham 1969; Graetz & Wilson 1979).

The second form of graphical summary was a 3-dimensional graph of which the base plane represented the paddock surface and the vertical axis was scaled in $\log_2$ SIP. The surface then was contoured in intervals of one $\log_2$ cycle with PSI as datum, thus exhibiting successive doublings (upwards) and halvings (downwards) of SIP from PSI. Rotation of these graphs allows perspectives of the spatial distribution of SIP as in Fig. 2 which was prepared as an example from the same data of Hilder (1964) as was Fig. 1.

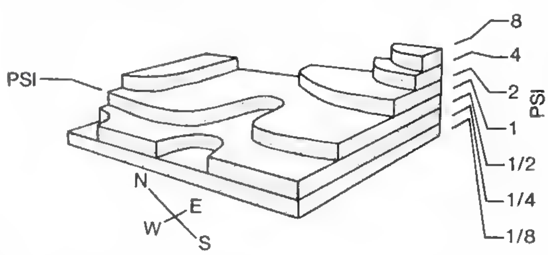

Fig. 2. Perspective view of a 3-dimensional graph showing the distribution of SIP values in the enclosure described by Hilder (1964). Values are grouped in class intervals of one $\log_2$ SIP cycle with PSI as datum. The scale expresses the SIP variation in terms of PSI.

Study Locality

The studies were conducted on Middleback and Nonowie stations near Whyalla, South Australia, an environmental context which already has been thoroughly described by Barker (1979), Jessup & Wright (1971), Rogers & Lange (1971) and Noble (1979) with maps and descriptions of most of the paddocks mentioned here. It is arid chenopod shrubland of *Atriplex* and *Maireana* with variable low woodland of *Acacia*, on undulating desert loams. Rainfall is very unpredictable and averages about 220 mm yr^{-1} (1940–1970). The whole region is fenced into paddocks approximately 1200–2000 ha which are stocked continuously with merino

TABLE 1. *List of studies undertaken in the Whyalla region, South Australia, to determine the magnitudes and distributions of SIP (stocking intensity of the part of the paddock in ha sheep⁻¹) in each case. PSI = paddock average stocking intensity.*

Study No.	Paddock name	Area (ha)	PSI (ha sheep^{-1})	Dates	Number of parts
1.	Wanga	1153	5.8	Aug. 1969–Feb. 1970 inc.	40
2.	Wertigo	2280	6.5	Oct. 1971–May 1972 inc.	37
3.	Wertigo	2280	6.5	June 1972–Sept. 1973 inc.	37
4.	Overland	1290	5.5	June 1978–Jan. 1979 inc.	50
5.	Two-Mile	1936	6.7	Sept. 1980–Nov. 1980 inc.	52
6.	Two-Mile	1936	6.7	Jan. 1981–March 1981 inc.	52
7.	Purpunda	1145	5.9	June 1982–Sept. 1982 inc.	59

sheep at PSI of about 6 ha sheep^{-1} (Lange, Nicolson & Nicolson 1984).

Validation Experiments

Validation that egesta accumulation was roughly proportional to flocktime spent by sheep in parts of the discussed paddocks was published by Lange & Willcocks (1978) and Lange (1983).

In the work of Ares & Leon (1972), validation of egesta accumulation as a useful variable to measure in pastoral research rested on the persuasiveness of its correlations with stock effects upon pasture plants. The same applied where distance from water was used as the stocking variable (Osborn, Wood & Paltridge 1932; Valentine 1947; Lange 1969; Barker & Lange 1969; Squires 1974; Graetz & Ludwig 1978; Barker 1979; Fatchen & Lange 1979). To provide an equivalent sort of validation that egesta accumulations (and hence SIP estimates) correlate with concomitant effects on vegetation in the Whyalla region, several experiments can be cited.

Lange (1984) showed that the observed probability of random outer shoots of saltbush (*Atriplex vesicaria* Heward ex Benth.) being grazed by sheep was largely accounted for by using concomitant sheep egesta accumulation as the independent variable in regression equations. Data were from bushes at arbitrary localities within 5000 ha of Whyalla shrubland ranged by sheep. The regression equation was

$$y = 11.80 + 0.17x,\ r^2 = 0.78,\ p < 0.01$$

where y was percent loss of marked shoots over a 6 week period and x was concomitant sheep egesta accumulation in kg dry wt, on plots 60 × 40 m. Across the different parts of small experimental paddocks stocked heavily, the relationship on plots 10 × 10 m was much clearer, namely

$$y = 0.416 + 0.004x,\ r^2 = 0.91,\ p < 0.001.$$

One further validation experiment* is reported here to extend demonstrations of the usefulness of egesta accumulation as an index of SIP, at least in some contexts. *Stipa nitida* Summerh. & C.E. Hubbard and *Danthonia caespitosa* Gaud. in Freyc. are prominent tuft grasses occurring between bushes in mixed chenopod shrubland of 2-Mile paddock (map and description in Barker 1979). A tract of this vegetation 30 × 200 m was fenced to include a drinking trough and was surveyed into 10 equal parts.

In each part all grass tufts >5 cm tall on a plot 20 × 0.2 m were estimated for biomass (g. dry wt., technique of Andrew, Noble & Lange 1979) and measured for height (cm). The enclosure was then stocked with 10 merino sheep for 6 days, the grasses then remeasured and egesta dropped by the sheep was collected from plots 28 × 2 m superimposed over the grass plots. The prediction was that egesta

* This experiment was performed by Chester J. Merrick, an Honours student in the author's programme.

accumulations would index reductions in grass height and biomass via regression equations.

Fullscale Studies of Paddock SIP

Table 1 lists studies which were undertaken between 1969 and 1982 (see Barker 1979, Noble 1979 and Lange, Nicolson & Nicolson 1984 for paddock maps). Wanga paddock lies east of Wertigo and Overland lies north of 1-Mile.

Results

Validation Experiment

The experiment yielded the very highly significant multiple regressions:

$y = 36.99 - 0.47x + 0.93z,\ r^2 = 0.99,\ p < 0.001$

where y = final mean grass height (cm),
x = egesta dry wt (kg)
and z = initial mean grass height (cm)
and $y = 14.31 - 0.15x + 0.95z,\ r^2 = 0.99,\ p < 0.001$
where y = final grass biomass (g),
x = egesta dry wt (Kg)
and z = initial grass biomass (g).

Full Scale Studies

Data from the seven separate paddocks were all the same in principle, differing only in detail of spatial pattern and particular history. A selection of data is presented here as a basis for discussion. None of the omitted cases tells a different story or contradicts the examples presented.

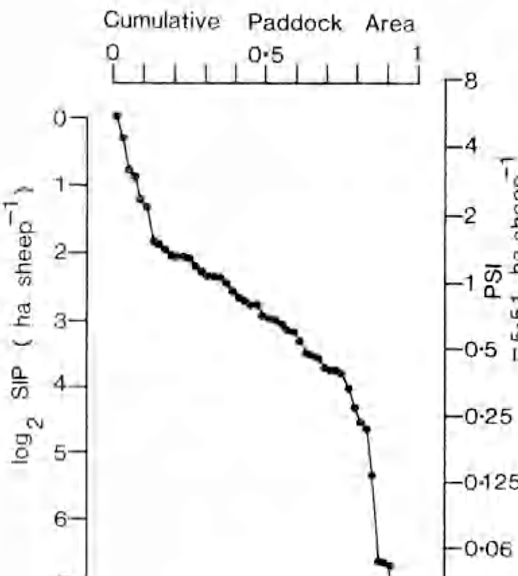

Fig. 3. The cumulative distribution of $\log_2$ SIP for the 50 parts of Overland Paddock June 1978–January 1979 inclusive (Study 4).

Overland Paddock (Study 4)

Fig. 3 shows the cumulative distribution of $\log_2$ SIP for the 50 equal parts of Overland Paddock for the period June 1978–January 1979 inclusive. Four parts accumulated no egesta during this period so SIP for them was ∞ ha sheep^{-1}. Over the used parts of the paddock SIP values graded smoothly upwards from PSI, over about one third of the area, to a highest intensity about 2.5 cycles (6×) above PSI. Over about two thirds of the used area they graded smoothly downwards from PSI to lowest measurable intensities about 4 cycles (16×) below PSI. Only 1 of the 50 parts actually had SIP = PSI.

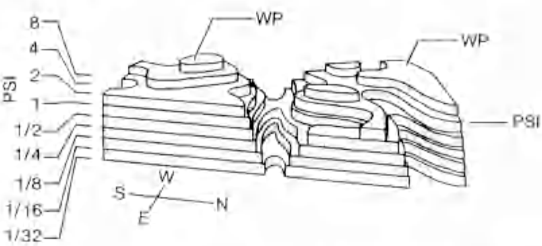

Fig. 4. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Overland Paddock (Study 4). Swamp Dam is the southern water point.

Fig. 4 shows the corresponding SIP surface of the paddock with $\log_2$ PSI as datum and with class-intervals of 1 $\log_2$ cycle. This spatial pattern had the following weather and flock management history. In June 1978 drought had restricted drinking sources for sheep in Overland paddock to Swamp Dam in the south part. The flock was observed to depend on Swamp Dam until it dried out. Then a temporary source of water was introduced (by pipeline) to a point at the west end of the north boundary of the paddock, to which the sheep were introduced.

Two-Mile Paddock (Studies 5 and 6)

Fig. 5 shows the cumulative distributions of $\log_2$ SIP for spring and for summer 1980–81, respectively, in 2-Mile paddock. Fig. 6 shows these distributions compared with a theoretical normal cumulative probability distribution for the 52 parts of the paddock. The diagonals represent required lines for perfect fit and the dotted lines show observed fit.

Rank order correlation of spring and summer SIP scores across the 52 parts of 2-Mile paddock was not significant, implying that the flock shifted

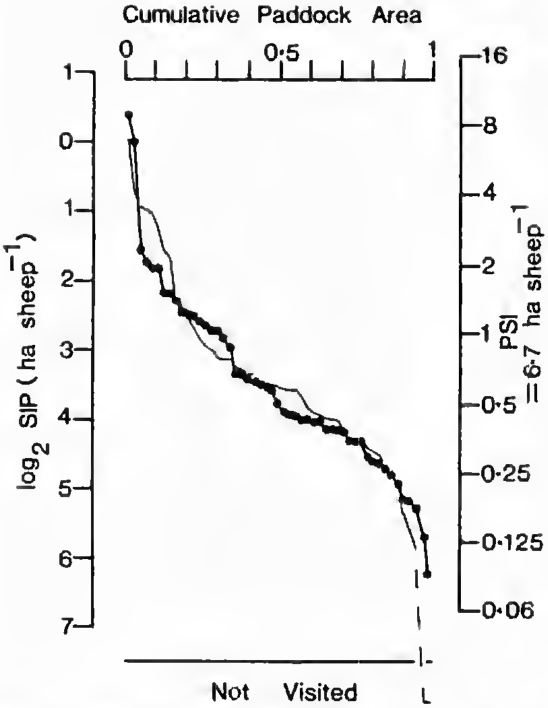

Fig. 5. The cumulative distribution of $\log_2$ SIP for the 52 parts of 2-Mile Paddock in spring (fine line) and summer (heavy line) 1980–81.

its pattern of paddock use from spring to summer, 1980–81. Hence the resemblance of spring and summer cumulative distributions is demonstrated to be independent of spatial shifting of use pattern.

Fig. 7 shows the SIP surface of 2-Mile paddock for the combined spring and summer periods. Peak stocking pressure was located not at the watering points but against the northern fence in a drainage line.

Wertigo Paddock (Studies 2 and 3).

Fig. 8 shows the SIP surface of Wertigo paddock for the period October 1971–May 1972 inclusive with $\log_2$ PSI as datum and SIP in class-intervals of 1 $\log_2$ cycle. The flock was observed throughout this period to use only the southwestern water point and to graze away from it in two directions, namely southeastwards into the southeast corner of the paddock and north along the western boundary. One part of the paddock was never visited.

Fig. 9 shows the corresponding surface for the period June 1972–September 1973. The flock was observed throughout this period to use Wertigo paddock in approximately the same pattern as previously. There was a highly significant rank correlation of SIP scores between the two periods ($r = 0.846$, $p < 0.001$), indicating relative stability

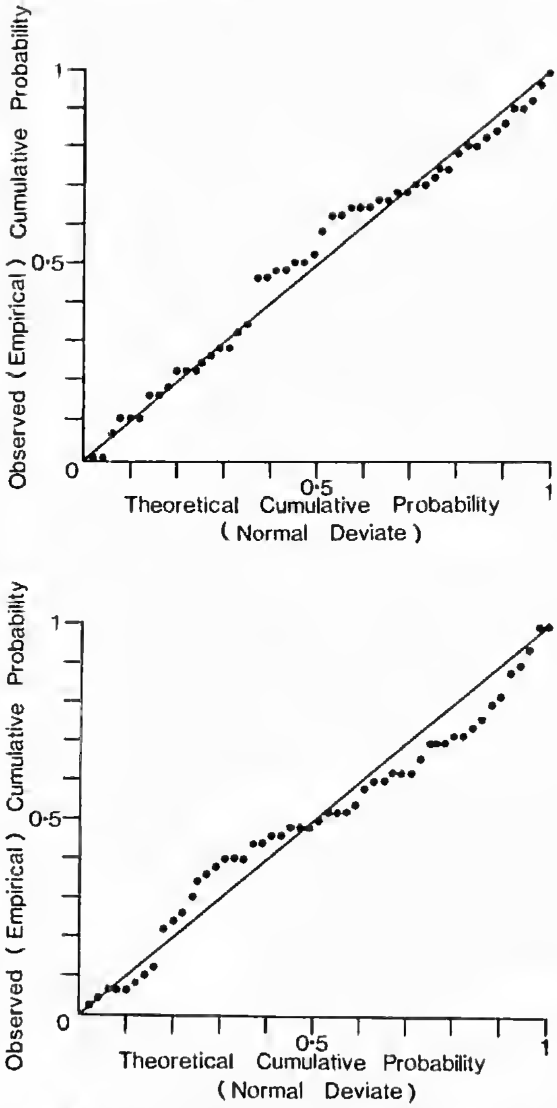

Fig. 6. The cumulative distributions of $\log_2$ SIP for spring and summer 1980–81 in 2-Mile Paddock compared with theoretical normal cumulative probability distributions. The diagonals represent required lines for perfect fit and the dotted lines show observed fit. Spring above, summer below.

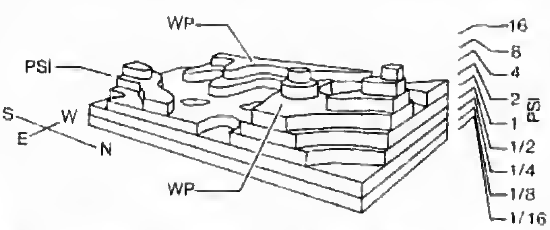

Fig. 7. Perspective view of a 3-dimensional graph showing the distribution of SIP values in 2-Mile Paddock for the combined period Spring and Summer 1980–81 (Studies 5 and 6).

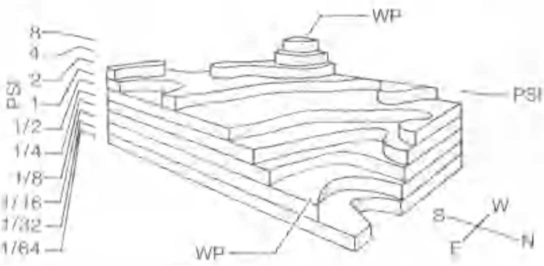

Fig. 8. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Wertigo Paddock for the period Oct. 1971–May 1972 inc. (Study 2).

Fig. 9. Perspective view of a 3-dimensional graph showing the distribution of SIP values in Wertigo Paddock for the period June 1972–Sept. 1973 inc. (Study 3).

of use pattern. Kangaroo egesta recovered from the same places also correlated between periods (r = 0.39, $p < 0.05$).

Discussion

The demonstrations by Rawes & Welch (1966, 1969) and by Ares & Leon (1972) that measurements of egesta deposition in open paddock situations index stocking intensities of sheep, are extended by the present data. That extension is not merely to the Australian arid zone context, but also towards a more quantitative footing.

Data reported here show very significant quantitative relationships between sheep egesta depositions and simultaneous effects on plants at localities throughout the range of the freely-roaming sheep flock. Furthermore those relationships have been demonstrated over time intervals so brief as to admit no scope for interpretations other than of egesta deposition as an index of simultaneous stocking or grazing pressure. The only logical conclusion from the regression equations of the validation experiment is that egesta accumulation on plots indexed the simultaneous loss of grass height and biomass caused by the sheep, and from the equation in Lange (1984) that it indexed the simultaneous eating of saltbush shoots by the flock.

To the extent that the SIP estimates reported here are direct transformations of the egesta deposition data, the SIP estimates also relate to effects of stock on vegetation. It is reasonable from the present evidence to suppose, if plants are being affected by stock in their paddock, that the plants are likely to be affected most where SIP estimates are highest and least where they are lowest. But the particular advance introduced here is the capacity to place quantitative estimates (ha sheep $^{-1}$) upon the SIP at particular places within the ranges of flocks, and thus to link those places with the extensive small-plot experimental literature mentioned in the Introduction. The results of examining those links will be discussed elsewhere; the aim here is to discuss intrapaddock SIP for its own sake.

Much evidence indicates fundamental similarities in the relationships of SIP in all paddocks examined from the Whyalla region and extending, so far as data exist, to published cases from elsewhere in Australia. Thus the logarithms of SIP values in each of the examined paddocks were approximately normally distributed. Something intrinsic in the behaviour of sheep flocks is suggested by that fact, constraining them to distribute their flocktime very unevenly, on average, throughout their range. Lest that be attributed simply to the vast range area available to relatively small flocks in the Whyalla region, or to the piosphere effect (Barker 1979), it should be recalled that the same applied even to Hilder's data concerning 20 sheep penned inside 1 ha.

That inflexibility has important practical implications. The first is that the more even spread of flocktime throughout each paddock, desired by station managers (Lange, Nicolson & Nicolson 1984), seems less likely to be achieved simply by further fencing of paddocks into smaller areas, than was earlier thought.

The second is in relation to absolute flocksize and paddock size, and PSI. It is traditional in the Australian sheep industry to make stocking comparisons just on the basis of PSI (in ha sheep $^{-1}$ or, in wetter more productive places, sheep ha $^{-1}$). But as shown in Fig. 5 of Lange, Nicolson & Nicolson (1984), any particular PSI (say, 6 ha sheep $^{-1}$) is set throughout the industry by widely different combinations of flocksize and paddock size. Present results show that even in the relatively small paddocks of the Whyalla region, SIP values reflect the limits to which flocks can or will range away from their water-point. There is no evidence to suggest that those limits are different in big paddocks.

It ought to be evident from this, and from the inexorable tendency of the flock to exert SIP values greater than PSI over about one third of the flock's realized range, that PSI becomes progressively more grossly misleading as an index of SIP, as paddocks and flocksizes increase at the one PSI. That is unless the larger paddocks have correspondingly more waterpoints, which in many Australian cases they do not.

There are other applications of the present approach which are independent of considerations of wool production and pasture. Over 60 species of rare and threatened Australian endemic flora are to be found scattered within the sheep paddocks that enmesh their remnant distributions in this region. Clearly their fate is closely related to the SIP they experience, whether high or low. It is important to establish what their situation is, by means of the present technique, as part of developing conservation measures for them.

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